Strategic minerals and
materials

BP-118E

STRATEGIC MINERALS AND MATERIALS

Susan M. Gentleman

Science and Technology Division
Research Branch
Library of Parliament
Ottawa

10 January 1985

LIBRARY OF PARLIAMENT

BP-118E

STRATEGIC MINERALS AND MATERIALS

Susan M. Gentleman

Science and Technology Division
Research Branch
Library of Parliament
Ottawa

10 January 1985

BACKGROUND PAPER FOR PARLIAMENTARIANS

Cat. No. YM32-2/118E

ISBN 0-660-12409-2

TABLE OF CONTENTS

CANADA

LIBRARY OF PARLIAMENT
BIBLIOTHÈQUE DU PARLEMENT

STRATEGIC MINERALS AND MATERIALS

INTRODUCTION

Our complex industrial society transforms basic raw materials into products whose properties and functions are precisely linked. An alloy, for instance, has a given chemical composition which imparts certain desirable characteristics suitable for the particular application. These characteristics such as hardness, resistance to corrosion or performance at high temperatures are known from the results of years of research. Indeed, our knowledge of materials enables us to custom-design a coating for the outside of the space shuttle which is able to withstand extremes of heat and cold, or a paint which does not chip.

All of this complexity, from simple nuts and bolts to military hardware, is ultimately dependent upon the availability of those raw materials which enter into industrial production. Raw materials, particularly mineral commodities, originate throughout the world, and form the backbone of international trade. Their distribution is not uniform as all countries are not equally endowed by nature; their selling prices and their ownership have often been the objects of international disputes. One need think only of the 1973 OPEC crisis or the 1978 war in Shaba Province in Zaire which cut off supplies of cobalt to the West to realize the possible impact of geopolitical events on the flow of raw materials to consumers.

Certain strategic minerals and materials have important military applications although their use is not exclusively confined to this sector. Other minerals and materials find more far-reaching applications in the objects of everyday life, and in industrial processing. Such materials, which are usually metals employed in small amounts in alloys, act

as limiting factors within the economy. A significant shortfall of supply would disrupt whole segments of industry, at least temporarily, until substitutes or alternative sources could be found. These materials are of critical rather than of merely strategic importance. Manganese, which is used as a desulphurizing agent in the manufacture of steel, has no effective substitute and thus is a critical material.

A. Strategic and Critical Metals

Table 1 gives the main uses of certain strategic or critical metals. Although the list only includes the more common metallic elements, these metals form the backbone of modern industrial technology. The list does not include other more exotic elements which have certain highly specialized uses.

B. Effect of Economic Blockades and Interruptions of Supply

Southern Africa holds a significant proportion of the world's reserves of several strategic commodities: in 1979 South Africa had 66.4% of the chromium, 37.2% of the manganese, 49.4% of the vanadium and 73.2% of the platinum group metals. The country is also an increasingly important producer of the ferroalloys including ferrochrome, ferromanganese and ferrovanadium. South Africa is also the most important supplier of industrial diamonds. In addition, the country serves as a conduit for the transportation of strategic commodities from some other countries in Southern Africa despite vast differences in political outlook.

Economic sanctions against Southern Africa by the countries of the United Nations, could have serious implications for the Western industrial economies which are more vulnerable than the countries included in Comecon to major disruptions.

The USSR supplies a significant proportion (about 35%) of the manganese and ferromanganese sold to Western countries including the United States.

TABLE 1: PRINCIPAL INDUSTRIAL USES OF CERTAIN STRATEGIC METALS

Metal	Principal Industrial Uses
Beryllium	electrical contacts, spot-welding electrodes, structural component for airframes
Chromium	hardener for steel, stainless steel, refractory brick
Cobalt	jet turbines, gas turbine generators, magnets, superalloys
Manganese	desulphurizing agent in manufacture of steel
Molybdenum	improves strength of steel at high temperatures, nickel-based alloys, missile and aircraft parts, catalyst in refining of petroleum
Nickel	magnets, stainless steel, pipelines
Niobium (also known as columbium)	alloys used in pipelines, airframes, superconducting magnetic wire
Platinum group (includes platinum, palladium, rhodium, osmium, iridium)	thermocouple elements, electrical contacts, electric furnaces, catalysts for petrochemical industry and in automobiles, fuel nozzles of jet engines
Tantalum	alloys, capacitors, parts for vacuum furnaces, optical glass
Titanium	airframes
Tungsten	machine tools, filaments for electric lamps
Vanadium	nuclear reactors, high-speed tools, catalyst for petroleum industry, superconducting magnets
Zirconium	coating for casting steel, nuclear reactors, refractory brick

C. Import Dependency

The countries of the European Economic Community and Japan are virtually dependent on external supplies for a group of 12 essential commodities (Table 2). In contrast, the countries which are members of Comecon are largely self-sufficient in these same commodities with the major exception of cobalt. This self-sufficiency is almost wholly due to the pre-eminence of the USSR with its huge, geologically diverse land mass and its deliberate policy of material self-sufficiency with little regard to external market forces.

The United States is also dependent on foreign sources for most of these 12 commodities; Canada is the most important supplier for seven of these materials. For some 20 essential minerals, the United States must rely on imports (Table 3), for more that 50% of its requirements. Canada is more fortunate; only six mineral commodities, vanadium, manganese, chromium, industrial diamonds, titanium and zirconium, must be imported in significant amounts.[1] Of these six commodities, the Resource Strategy and Economic Branch of Energy, Mines and Resources considers that only manganese and chromium appear to merit active concern.[2] Nevertheless, Canada relies on imports for 76 commodities (see Table 4) although many of these products are pure metals and alloys processed in the United States from ore and concentrates produced in Canada.[3]

D. U.S. Policy Initiatives

In 1980 the U.S. Congress passed the <u>National Materials and Minerals Policy, Research and Development Act</u>. This Act designated the Office of the President to produce a plan for essential materials and emphasized the areas of substitution and research. The President's National Materials and Minerals Policy Program Plan of April 1982 led to the

---

(1) Canada, Energy, Mines and Resources. <u>Mineral Policy: A Discussion Paper</u>, Report MP81-1E, December 1981.

(2) Ibid.

(3) Ibid.

TABLE 2: COMPARISON OF IMPORT DEPENDENCY FOR STRATEGIC MATERIALS OF THE UNITED STATES, THE EUROPEAN ECONOMIC COMMUNITY, JAPAN AND COMECON

	U.S.	E.E.C.	Japan	Comecon
	(percent)			
manganese	98	100	98	3
cobalt	97	100	100	68
bauxite	91	97	100	28
chromium	91	100	98	2
asbestos	85	90	98	1
nickel	70	100	100	13
zinc	57	91	74	9
iron ore	48	82	100	5
silver	36	93	71	10
copper	13	100	97	4
lead	13	76	78	3
phosphate	(exporter)	99	100	23

Source: U.S. Bureau of Mines, 1979.

TABLE 3: U.S. DEPENDENCY ON IMPORTED COMMODITIES

Commodity	% of dependency on imports	Country(ies) of origin
niobium	100	Brazil, Thailand, Canada
mica (sheet)	100	India, Brazil, Malagasy Republic
strontium	100	Mexico, Spain
manganese	98	Gabon, Brazil, South Africa
tantalum	97	Thailand, Canada, Malaysia, Brazil
cobalt	97	Zaire, Belgium-Luxembourg, Zambia, Finland
bauxite and alumina	93	Jamaica, Australia, Surinam
chromium	92	South Africa, U.S.S.R., Zimbabwe, Turkey
platinum group	91	South Africa, U.S.S.R., U.K.
asbestos	84	Canada, South Africa
fluorite	82	Mexico, Spain, South Africa
tin	81	Malaysia, Bolivia, Thailand, Indonesia
nickel	77	Canada, Norway, Dominican Republic, New Caledonia
cadmium	66	Canada, Australia, Belgium-Luxembourg, Mexico
zinc	62	Canada, Mexico, Australia, Belgium-Luxembourg
potash	61	Canada, Israel, West Germany
selenium	61	Canada, Japan, Yugoslavia, Mexico
mercury	57	Algeria, Canada, Spain, Mexico, Yugoslavia
gold	54	Canada, Switzerland, U.S.S.R.
tungsten	50	Canada, Bolivia, Peru, Thailand
antimony	48	South Africa, Bolivia, China
silver	41	Canada, Mexico, Peru, U.K.
barium	40	Peru, Ireland, Mexico
titanium (as ilmenite)	39	Canada, Australia
gypsum	34	Canada, Mexico, Jamaica, Dominican Republic
iron ore	29	Canada, Venezuela, Brazil, Liberia
vanadium	27	South Africa, Chile, U.S.S.R.

Source: U.S. Bureau of Mines, 1979.

TABLE 4: CANADIAN IMPORT RELIANCE FOR MINERALS AND RELATED COMMODITIES (1979)

COMMODITY		% IMPORT RELIANCE
Lightweight aggregates:	pumice, perlite, vermiculite other (1978)	0
Aluminum:	bauxite	100
	alumina (1978)	45
	primary aluminum (1978)	0
Antimony:	ores and concentrates	0
	lead alloy	92
	oxide; metal	100
Asbestos:	crude; manufactured	0
Barite:	crude, ground and chemical	0
Bentonite		75
Beryllium:	metal; alloys	100
Bismuth:	ores and concentrates; metal	0
Boron:	boric oxide, sodium borate, ferroboron	100
Bromine:	ethylene bromide	100
Cadmium (1978):	ores and concentrate; metal	0
Calcium:	metal	0
Cement:	portland and other; products; refractory	0
Cesium:	pollucite	px*
	metal and compounds	np,ndc*
Chromium:	ores and concentrates, ferro-chromium, others	100
Clays:	common clays and shale	0
	fireclay (1978)	26(am)*
	ballclay	na*
	Kaolin (china clay)	100
	fuller's earth	29
Cobalt (1978)	ores and concentrates; metal; oxides	0
Columbium:	pyrochlore (1978)	px*
	ferrocolumbium	100

... continued

TABLE 4: CANADIAN IMPORT RELIANCE FOR MINERALS AND RELATED COMMODITIES (1979)(CONT'D)

COMMODITY	% IMPORT RELIANCE
Copper (1978): ores, concentrates and scrap; refinery shapes; products	0
Diatomite	95
Feldspar	100
Fluorspar and natural cryolite (1978)	100
Gallium: metal	0
Germanium: in zinc concentrate	px*
metal	na*
Gold: all forms in aggregate	0
Gypsum and anhydrite	0
Halfnium	ndc,p*
Indium	0
Industrial diamonds: stone and dust	100
Iodine	100
Iron ore (1978)	0
Iron and steel	0
Kyanite	100
Lead (1978) ore, concentrates and scrap; fabricated	0
Lime	0
Lithium compounds	100
Magnesium metal and alloys	0
(1978): magnesite	69
Manganese: ores and concentrates; metal	100
ferromanganese (1977)	6
silicomanganese and spiegeleisen (1977)	47.5(am)*
Mercury	100
Mica: block, sheet and ground	70
Molybdenum ores, concentrate and scrap; oxides; ferromolybdenum (1978)	10-12
Natural abrasives	100

... continued

TABLE 4: CANADIAN IMPORT RELIANCE FOR MINERALS AND RELATED COMMODITIES (1979)(CONT'D)

COMMODITY		% IMPORT RELIANCE
Natural graphite		100
Nepheline syenite		0
Nickel:	all forms in aggregate	0
Phosphate rock and ferrophosphorus		100
Platinum group (1978):	ores, concentrates and scrap	0
	refined	100
Potash:	fertilizer potash	0
Pyrophyllite (1978)		0
Rare earths:	concentrate	nc,p*
	compounds and ferro-	
Refractories (firebrick and similar shapes) (1978):	total	52.5
	magnesite only	77
	silica only	84.5
Rhenium:	ores and concentrates	px*
	perrhenic acid	np,ndc*
	metal	ndc,p*
Rubidium		ndc,p*
Salt		0
Sand and gravel		0.33
Selenium		0
Silica metal; ferrosilicon		0
(1978):	sand, quartz and silex	46
	ferroalloys	na*
	crude artificial abrasives	0
	refined artificial abrasives	100
Silver:	ores and concentrates; metal	0
Sodium:	sulphate	0
	metal	100
Stone crushed		0.67
(1978):	rough	3
	shaped or dressed	59(am)*
	crude (nes) and basic products	0

... continued

TABLE 4: CANADIAN IMPORT RELIANCE FOR MINERALS AND RELATED COMMODITIES (1979)(CONT'D)

COMMODITY		% IMPORT RELIANCE
Strontium carbonate: celestite; compounds		na*
Sulphur (1978): crude and refined; acid and oleum		0
Talc (1978)		58.5
Tantalum:	pentoxide (1978)	0
	metal and alloys	100
Tellurium		0
Thallium		ndc,p*
Thorium		na*
Tin:	ores, concentrates and scrap (1978)	0
	tinplate	36.5
	metal	95
Titanium:	slag and dioxide (from ilmenite)(1978)	0
	metal (from rutile)	100
	ferrotitanium (1978)	90-100
Tungsten:	ores and concentrates	0
	ferrotungsten	100
	metallic carbides (1978)	42(am)*
Vanadium:	ores and concentrates; pentoxide; alloys	100
	ferrovanadium (1978)	0
Zinc:	all forms in aggregate	0
Zirconium:	all forms	100

Source: Canada, Energy, Mines and Resources Mineral Policy: A Discussion Paper, Report MP8-E, December 1981, p. 24-25.

* am - at most

nc,p - no domestic consumption, production

ndc,p - no definite domestic consumption, production

na - not available

px - produced entirely for export

nes - not specified elsewhere

Committee on Materials (COMAT) which involves several agencies and includes a Working Panel on Essential Materials as a subcommittee. In addition, the National Materials Advisory Board which existed previous to the Act advises the Government in the area of materials research. The National Bureau of Standards, the Department of Defense, the Department of Environment, the National Academy of Sciences and the U.S. Bureau of Mines have all made contributions to mineral and materials policy.

Under the Defense Production Act, Title 1, defence contracts and orders are assured preference for delivery of materials in the event of a national emergency.

1. Countermeasures

Countermeasures and precautions against supply disruptions fall into two categories:

(1) Strategic or supply-oriented
(2) Technical or use-sensitive

The first category includes recycling, exploitation of previously sub-economic mineral deposits, stockpiling of ores and various grades and forms of refined materials, as well as active exploration for new mineral deposits. Use-sensitive options include material substitutions and reductions. Basic research into alternative materials which are less constrained by supply considerations and new processing technologies is another side of technical countermeasures. Maintenance and distribution of technical information is equally important. Substitutions are by far the most promising route for countries highly dependent upon external suppliers.

In 1982 a House of Lords select committee recommended that the British Government stockpile strategic metals used in the defence and aerospace industries.(1) In March 1983 the Government established a small stockpile worth £100 million, which probably includes chromium, manganese, cobalt, vanadium, nickel, tungsten and tantalum, to be kept in

---

(1) United Kingdom, House of Lords, Select Committee on the European Community's Strategic Minerals, Session 1981-82, 20th Report, Her Majesty's Stationery Office, London, 1982.

secret locations.[1,2] In 1975 France set spending targets to stockpile metals including copper, lead, tungsten and chromium which are administered by the Minister of Industry and Technology. Japan stockpiles a number of commodities including nickel, chromium, cobalt, titanium, manganese and vanadium.

Transnational corporations also have a certain role to play in the balance of commodities. Resource companies count among themselves some of the largest, most powerful corporations on earth, with corresponding access to capital, technology and the political sphere. Concerted effort on the part of Western companies to find and exploit alternative ore deposits without compromising economic efficency would be a major counterweight to the concerns of Western Governments about the political reliability of Southern Africa and the Soviet Union.

Canada could combine its desire for access to markets and its goals in resource diplomacy by encouraging foreign investment in the form of joint ventures for exploration and development of new mineral properties.[3] If minerals were included in such accords as the North American Defence production-sharing agreement or the NATO agreement, Canadian mineral production could be coordinated with the larger goal of enhanced security of the Western alliance.[4]

2. Substitutions

Substitutions are available for strategic materials which may in future be subject to supply disruptions. Not all of the concerted motivation for substitution comes directly from considerations of security; much research into substitution is conducted with the aims of reducing material and manufacturing costs as well as of improving performance. Secondary considerations such as saving energy also enter into material substitutions.

---

(1) "U.K. stockpiles certain metals", Globe and Mail, 15 March 1983.

(2) Peter March, "The West builds up its metals mountain", New Scientist, 3 March 1983, p. 573-577.

(3) Patrick J. Caragata, National Resources and International Bargaining Power: Canada's Mineral Policy Options, Centre for Resource Studies, Queen's University, Kingston, Ontario, 1984.

(4) Ibid.

Generally, most substitutes for strategic metals are non-metallic materials which include ceramics, polymers, composite materials, coatings and claddings. New technologies such as rapid solidification technology which produces glassy metals and powder compaction technology may be utilized.

Those materials and technologies which originate in defence research will require a strong civilian market to develop an industrial capacity. Assembly lines using parts manufactured of substitute materials may require considerable reorganization; however, these new materials may also enable other savings such as a reduction of the number of parts required and simplified manufacturing techniques such as net shape forming in which the final shape of the part is produced from the outset.

a. Ceramics

The ceramics industry requires few raw materials in short supply. Only lithium (usually in the form of the minerals lepidolite or petalite), the rare earths and strontium could be considered scarce commodities. Fluorite, bauxite, cryolite (natural cryolite or a byproduct of the aluminum industry), magnesite and nepheline syenite (a natural sodium aluminosilicate) are the principal raw materials required. Small amounts of antimony, manganese, nickel, cobalt, chromium and precious metals are also used.

Ceramic materials are characterized by their hardness, resistance to wear and corrosion, high strength, and low density. Some ceramic materials are also extremely durable at high temperatures. These properties lend themselves to numerous potential applications. However, ceramics are also brittle and prone to fracture along flaws. Different designs for metallic and ceramic components are often required because ceramic materials may not be uniformly resistant in all directions.

Ceramic materials are currently employed in dies, tools, bearings, seals, fitters, heat exchangers, high temperature coatings, composites, sensors and catalysts.

The Toyota piston insert was the first commercial application of ceramic composite materials in the automobile industry. Extensive research is being conducted into the use of ceramics in heat engines. An uncooled ceramic engine operating at higher temperatures than a conventional metal-based engine could be capable of realizing a 30% improvement in fuel economy. Such an engine could also be used with alternative fuels and have competitive costs initially and over the life cycle of the vehicle. Turbine engines and uncooled diesel engines are also being developed. By the end of this decade, most engine parts could be made of ceramic materials; sometime in the next decade ceramic materials could find applications in minimum friction diesel engines, aircraft propulsion engines and the first wall of fusion reactors.

Ceramic materials may replace cobalt, tantalum, tungsten, and vanadium to a certain degree in cutting tools(1) which are an essential part of heavy industry.

b. Composite materials

Composite materials are very diverse in nature and include graphite-reinforced polymers, graphite/aluminum, graphite/magnesium, glass-ceramic composites, silicon carbide-oxide composites as well as refractory carbides, borides and nitrides.

Graphite-epoxy has found extensive applications in aircraft parts since NASA established a program for aircraft energy efficiency in the mid-1970s. Although the original aim was to reduce weight of the component parts, replacement with epoxy composites also reduces the amount of the titanium metal in the aircraft structure. Aviation accounts for 10% of the use of titanium metal in the United States.

The Space Shuttle has graphite-epoxy composites in its bay doors and the outer surface of the pods. Spacecraft are a major focus for new application of fibre-reinforced polymers. Satellites have antennae, booms, struts and support trusses made of fibre-reinforced polymers.

---

(1) D.H. Reneke, "Substituting non-metallic materials for vulnerable minerals" Materials and Society, v. 8, p. 195-200.

Graphite-fibre composites are now employed in drive shafts, leaf springs, body components and bumpers. Ford Motor used graphite-fibre components to the maximum extent in experimental versions of the 1980 Granada and saved 1200 lbs over the standard production models.

Various production models have utilized graphite fibre to achieve weight reductions between 18 and 30%, including the DC-10 rudder and vertical fin, the ailerons and vertical fin on the L-1011, the elevators on the Boeing 727 and the horizontal tails on the 737. The number of parts in these components was effectively halved. In the F-18, the horizontal stabilizer, the wing planes and most of the wing feathers are composed of graphite polymers. The Learfan 2100 is nearly all graphite epoxy except for the engine, the landing gear and the wing-attach fittings.

Automobiles will eventually use graphite-reinforced plastics in the hood, the trunk lid and the structural frames - the areas which are more prone to stress.

Polymers could replace or reduce the amount of platinum, palladium or rhodium used for catalyst or catalyst-support in the petrochemical industry.

c. Substitution of one metal for another

Substitutions do not always involve new materials. Relatively well-known properties of metals enable direct substitution of one metal or compound for another. In a national emergency any disadvantages of such substitutions, such as durability of the material, may be outweighed by the scarcity of the original metal. Thus molybdenum can replace tungsten in high-speed tool steel, molybdenum carbide and vanadium carbide can replace cobalt in high-speed steel and niobium carbide can replace tantalum carbide in cemented multi-carbide tools. Polymeric coatings may also protect against corrosion.

A major concern for North American industry is finding a substitute for chromium.(1) Sixty percent of the chromium metal consumed

---

(1) United States, National Academy of Sciences, Contingency Plans for Chromium Utilization, Publication NMAB-335, 1978.

is utilized to make stainless steel. One of the most important applications of high-chromium stainless steel is in combustion systems for fossil fuels. Twenty percent is used to make refractory brick although this use has been decreasing and could be considerably reduced. Chromium-free steel and iron-aluminum-manganese carbide could substitute for high-chromium stainless steel.(1) Tantalum, niobium, tungsten, molybdenum and beryllium could substitute for chromium in super alloys. Intermetallic components such as nickel aluminide may also substitute for stainless steel.

3. Recycling and Conservation

Recycling of metals is already a complex industry in itself. Now scrap and recovered metal are important components in the budgets of many strategic metals, especially cobalt, chromium, titanium and platinum. New technologies such as duplex melting, continuous casting, net shape casting, and coatings could conserve such metals as cobalt and titanium considerably.

4. Update of Research

Basic research into the economic repercussions of a shortfall in strategic metals and material substitutions is crucially important. Knowledge of alternative materials and technologies constitutes an "intellectual stockpile" which should be readily accessible to industry.

In the United States, President Reagan's National Materials Progress Plan and Report to Congress recommended that any government-funded research and development activities should focus on long-term, high-risk, high-potential projects with an optimum chance of widespread generic applications to material problems and increased productivity. Many government and industry specialists however regret the lack of a coordinated national research and development program and the lack of a national commitment to long-term funding.(2)

---

(1) Richard S. Stein, "The impact of polymeric substitutes on critical and strategic applications of imported materials", Materials and Society, v. 8, 1984, p. 397-410.

(2) D.H. Reneker, "Substituting non-metallic materials for vulnerable minerals", Materials and Society, v. 8, 1984, p. 195-200.

The Japanese Ministry for International Trade and Industry has a polymers program which is of equal importance to those for electronics and biotechnology. Graphite-fibre and ceramics research commitments exceed those of American industry. The Soviet Union has 23 research organizations employed in the development of alternative materials in a program which greatly exceeds that of the United States.[1] These alternative materials naturally find application overwhelmingly in military hardware.

The Department of Defence has a program which covers 11 applications in the field of ceramic composites.[2] Other areas of immediate interest include rapid solidification technology, coatings, production techniques and polymer fibres. The Office of Vehicle and Engine Research and Development in the U.S. Department of Energy is conducting research into advanced heat engine technology.[3] Limitations imposed on the exploitation of fossil fuels, nuclear fission, solar energy and geothermal energy by material and potential material shortages are also considered. NASA has an extensive materials program in polymer matrices and ceramic matrices.[4]

5. Stockpiling

The best defence against material shortfalls whether from military disruptions, economic sanctions or preemptive buying may be stockpiling by both industrial users and government agencies. Industrial users habitually maintain a few months' supply of these commodities to hedge against short-term price fluctuations but consider that storage costs over a longer time period, except in times of national crisis, outweigh the

---

(1) Jerome Persh, "Department of Defence Program", Materials and Society, v. 8, 1984, p. 167-172.

(2) Ibid.

(3) Robert Schulz, "Non-metallic research activities in the Office of Vehicle and Engine Research and Development, U.S. Department of Energy", Materials and Society, v. 8, 1984, p. 173-187.

(4) Charles Bersch, "NASA Programs", Materials and Society, vol. 8, 1984, p. 189-193.

advantages of maintaining a stockpile. It has therefore fallen to government agencies in many countries to accumulate stockpiles of strategic commodities. These stockpiles carry their own risks. Technological change may make a given physical form or a given alloy less desirable and may necessitate upgrading by the end user.

The United States, Japan, Britain, France, Sweden, Spain, South Korea and Italy have stockpiles of strategic materials. West Germany has an incentive scheme to facilitate stockpiling in the private sector although this policy has met with little success.

Since 1950 the General Services Administration in the United States has stored over 90 strategic commodities, worth $12 billion in 1983 dollars, including aluminum, cobalt, chromium, manganese, tin, silver, platinum, iodine, mercury and rubies. In 1977 President Carter requested an interagency review of federal nonfuel minerals policy. Phase I of this review was to concern itself specifically with policy issues; Phase II was intended to address the major concerns regarding strategic minerals and materials. Their study was conducted by Resources for the Future under contract with the Office of Science and Technology in the Executive Office of the President.

The study signalled four mineral commodities as critically important to the American industrial and military economy and ranked them in order of strategic vulnerability: 1. manganese 2. chromium 3. cobalt and 4. aluminum.(1) During the 1980 presidential campaign, strategic minerals emerged as an issue in the larger context of American military preparedness.(2) Ronald Reagan tied the strategic interests of the United States to his policy of rapprochement with South Africa. Supporters of the Reagan campaign deplored the slow growth of the stockpile toward established goals.(3)

---

(1) United States, National Technical Information Service, Major minerals supply problems, N.T.I.S. PB 80-117674, 1980.

(2) "Minerals emerge as campaign issue", Aviation Week and Space Technology, 20 October 1980, p. 115.

(3) Barry Goldwater, "U.S. Dependency on Foreign Sources for Critical Material. The Military Industrial Base", Vital Speeches of the Day, vol. 47, no. 17, 15 June 1981, p. 517-520.

In office, President Reagan announced his intention to build up American stockpiles of strategic materials while also divesting the stockpile of its less important stocks of silver and tin.

E. Canadian Policy

During the Second World War the Canadian Government coordinated a program through the Department of Munitions and Supply to replace scarce strategic minerals and materials with synthetic substitutes and metals from previously subeconomic sources.(1) Most of the organization was established through the Cabinet by order-in-council.

In July 1940 the Department established a Metals Controller who had the power to buy, sell, mine, process, store and transport minerals, ores, metallic products, metals and alloys of these metals. Three divisions within the Department regulated this program including Administration, the Development Division which regulated existing metal and mineral production and the Allocation and Conservation Division which was responsible for finding substitutes for critical metals and for allocating available supplies from private and government-financed mines and from stockpiles. The Statistical Section of this Division cleared all of the metal requirements of the Canadian war programs and correlated these requirements with civilian needs and exports.

In May 1942 the Department created the War Metals Advisory Committee to make recommendations for increases in the production of base metals which were in short supply among the Allies. By early 1943 Canada had become the world's largest exporter of base metals and contributed 94% of the nickel, 32% of the aluminum, 20% of the zinc, 17% of the lead, 10% of the copper and 75% of the asbestos utilized by the Allied forces.

The Department established a Directorate of Metallurgy to deal with the metallurgical problems of the armed forces and to advise the

---

(1) The history of the Department of Munitions and Supply's program for strategic minerals and materials during the Second World War is taken from J. de N. Kennedy, History of the Department of Munitions and Supply. Canada in the Second World War, King's Printer and Controller of Stationery, 1950.

Inspection Board of the United Kingdom on the acceptance of materials and changes in manufacturing processes necessitated by the transfer of British Technology to Canadian industry. In 1943, when Malaya, the Dutch East Indies, Siam and Burma fell to the Japanese, the supply of tin to North America and Europe was cut off. The Directorate issued a list of approved brass and bronze alloys which reduced the amount of tin required. As the war progressed the quality of steel scrap deteriorated, necessitating changes in specifications and an organized program of substitutions.

The Wartime Metals Corporation created as a crown corporation in 1942 undertook the development of subeconomic mineral properties. Three mercury deposits were mined in British Columbia to replace imports from Spain. Two molybdenum mines began producing in 1943, one under the operational direction of the Corporation and the other managed by Dome Mines making Canada self-sufficient in this metal for the first time. A major expansion of the Sudbury operations of Inco and Falconbridge in 1943 was mostly motivated by the war effort. Fly ash from the combustion of coal was processed to extract vanadium. Tin and antimony were recovered as by-products from the Sullivan mine in British Columbia. Tungsten was recovered as by-product of gold mining. Consolidated Mining and Smelting Co. in Trail, B.C. (now Cominco) produced atomized magnesium powder. The Chromeraine project in Black Lake, Quebec in the Eastern Townships produced chromite beginning in 1943. Pitchblende deposits at Great Bear Lake were expropriated by the Government. Exploration for iron ore resulted in the discovery of major deposits in Ungava and the Labrador Trough as well as the opening of the mines at Steep Rock, Ontario.

Other materials were in short supply. Abrasives, such as corundum (used as an insulating material in radio equipment and refractory brick), sphagnum moss, fertilizer, talc, cerium oxide, muscovite and graphite were also monitored by the Department.

As the war wound down in 1944 operations at several of these sites were closed. The Chromeraine project was terminated in August 1944 with an accumulated stockpile of 9,000 tons of chromite. In October 1945 controls on tin, tin alloys, antimony, steel scrap, radium, uranium and cadmium were lifted.

The Second World War accelerated the process of industrialization in Canada, and with it metal mining, to supply that industrial base and those of the other Allied nations. Transfer of new technologies to Canadian plants stimulated exploration and development of metals which had previously been untapped; new processes also created demand for raw materials.

Concern in an uncertain world about the responsiveness of Canadian industry to a national emergency or disruptions of supply through economic boycotts has prompted a review of Canadian policy on strategic minerals and materials. The Mineral and Metals Strategy Branch of the Mineral Policy Sector of Energy, Mines and Resources has produced a series of monographs on key materials for which Canada is dependent on imports[1]. Three of these metals, vanadium, chromium and manganese, are imported directly or indirectly (via the United States) from Southern Africa. Australia supplies most of Canada's zirconium in the form of zircon sand, but South Africa is also a source of the mineral baddeleyite which is a more economical form of zirconium.

Most of the 3,000 to 4,000 tonnes of zirconium utilized per year in Canada is consumed in foundry applications. Zirconium alloys are employed in the cladding of fuel bundles, pressure tubes, calandria tubes and reactivity control mechanisms in CANDU reactors. A deposit of rare minerals, including zirconium, is located at Strange Lake, near the Quebec-Labrador boundary. The Athabasca tar sands could also be exploited for zircon as a by-product. Ontario Hydro maintains a nine months' stockpile of nuclear fuel bundles.

Canada consumes about 600 tonnes of vanadium per year in the form of ferrovanadium which is used in steel-making. About 50% of this material originates in the United States where vanadium is extracted as a by-product of uranium mining. Vanadium pentoxide flake is imported mostly from South Africa; vanadium-bearing master alloys are imported from the

---

(1) These include Vanadium (MR 188), Chromium (MR 196), Zirconium (MR 202) and Manganese (to be published shortly).
A more general review of the subject has been made by Energy, Mines and Resources, R.J. Schank, Canada's dependence on imported minerals and metals: The issues, MRI 80-7 (an internal report) and Imported minerals and materials: Guidelines for research policy, MRI 80-8.

United States and Europe. In the event of supply disruptions, the United States would be capable of making up shortfalls; the General Services Administration's stockpile plays a significant role in the economy of vanadium.

Canada has consumed between 25,000 and 35,000 tonnes of ferrochromium a year over the last decade. About 25,000 tonnes of chromite are also imported for the manufacture of refractory bricks and mortar. Of chromium-bearing materials ferrochromium is the most critical to the economy. South Africa is increasing its share of world capacity to produce ferrochromium. Low-grade chromite deposits occur in the Bird River area of Manitoba and in the Eastern Townships in Quebec. Metallurgical testing has indicated that these deposits could be exploited.

Ultimately, Canada, as a relatively small user of strategic materials, is dependent on the United States and, to a lesser extent, other Western allies, both as suppliers of refined products containing strategic materials and as originators of the technologies employed. Canada participates in two NATO committees, the Economics Committee and the Industrial Planning Committee, for which External Affairs coordinates the Canadian representation. A senior official in the Department of Regional Industrial Expansion is chairman of the Industrial Planning Committee which considers emergency planning including strategic materials.

Coordination of strategic supplies among the allies in the Second World War was relatively simple when North America was scarcely touched by the war and wholesale transfer of technologies was accomplished easily. Modern technologies, particularly aerospace and military technologies, are considerably more complex. Furthermore, many processes employing strategic materials and particularly their substitutes are governed by security classifications in the United States and elsewhere. The U.S. Export Administration Act controls exports to protect national security, to achieve foreign policy goals or to prevent the depletion of goods in short supply. A list of militarily critical technologies is administered by the U.S. Department of Commerce. Industry is also reluctant to share proprietary information. Canada is particularly

---

(1) Canada, Mines and Resources, Zirconium, MR-202, 1984.

vulnerable in the area of advanced composite materials which are increasingly substituting for strategic metals. Only very modest sums have been spent on research in Canada in this important area -- probably in the neighbourhood of 1% of the corresponding amount spent in the United States in the last 10 years.

CONCLUSION

Canada has no coherent policy addressing the issue of strategic minerals and materials, although recently the Mineral Policy Sector of Energy, Mines and Resources has considered various aspects of individual commodities including the Canadian industrial base, world reserves and possible Canadian sources. Although Canada is relatively fortunate compared to Western European countries and the United States, in that the country is less dependent on imported mineral commodities, nevertheless, Canada's industrial system is vulnerable to disruption of supply. Manganese, chromium, vanadium, zirconium and industrial diamonds all come from sources which are particularly susceptible to economic boycotts and other political manipulation.

There are a large number of substitute materials and technologies which may also offer economic advantages and superior performance. Their application, however, depends on the adaptability of industry and on the availability of technical information and expertise.

During the Second World War, Canada adapted rapidly to shortages of militarily important materials and to new technologies employing them. The structures put in place to channel the use of strategic materials were rapidly dismantled after the war and interest waned. During the late 1970s increasing East-West tensions stimulated interest in strategic materials in the United States. New legislation and a Presidential mandate brought the issue back into the public eye as the theme of military preparedness was once again in favour.

FURTHER REFERENCES

(1) Finlayson, J., "Canada and strategic minerals", International Perspectives, September/October 1982, p. 18-21.

(2) United States, Congress, Congressional Budget Office, Strategic and critical nonfuel minerals: Problems and policy alternatives. A CBO Study, Washington, August 1983.

(3) United States, General Accounting Office, Foreign Governments' Stockpile Policies - Actual and Proposed. (GAO/-10-83-16), Washington, December 1982.

(4) Information on the National Defense Stockpile in the U.S. is published bimonthly in Minerals and Materials A Bimonthly Survey, Bureau of Mines, United States Department of the Interior.

0 50505 25074 5